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Composition and Health Hazards of Water-Based Construction Paints: Results from a Survey in the Netherlands

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Water-based construction paints may have beneficial effects toward man's occupational and general environment when compared to traditional paints that contain large amounts of organic solvents. The aim of this study was to describe the health hazards of the application of these alternative paints. The composition of these paints was obtained by a questionnaire survey among the main producers and importers in The Netherlands. Physicochemical parameters and toxicity data of the constituents were used to estimate occupational and environmental health hazards. Mucous membrane or skin irritation and sensitization are predicted to be the most frequently occurring health hazards after contact with these paints during professional or do-it-yourself application. Health hazards from environmental pollution may be irritation of the mucous membranes when the indoor environment is painted and fish mortality due to slowly degradable polyacrylate binders. The health hazards can be reduced by replacing some toxic compounds with less toxic ones and by hygienic (ventilation, skincare, no cleaning of application materials under the tap) measures.

Introduction

In the 1970s there was a substantial change in the consumption of construction paints in many countries. Today more than 90% of construction paints in Scandinavian countries are water based (*1*). In Germany, some water-based construction paints (WCP) have the image and label of "environmentally safe products," which makes them popular with do-it-yourself painters. In the U.S., WCP are mainly used outdoors as stains (*2*). In other Western countries, WCP are mainly used outdoors as alternatives to the traditional enamels. Paints of the latter type contain about 50% volatile organic solvents (mainly white spirit), that may cause chronic or acute neurotoxic effects in painters (*3,4*). Moreover, emitted volatile organic compounds (VOC) can interfere with the nitrogen cycle, generating oxidizing compounds, like ozone, causing acute and chronic effects on the human respiratory tract (*5*). In The Netherlands, construction painting is the major contributor to the VOC emission of the painting trade (*6*). Moreover, this emission cannot easily be controlled because construction painting is a discontinuous point source.

The composition and health hazards of different kinds of WCP have been studied in Denmark (*1*). However, in contrast to the latter study which made no restriction to the type of WCP, we only evaluated alternatives to solvent-rich paints. Wall paints have been water-based for several decades already and are therefore not alternatives for solvent-rich paints. The aim of this study was to investigate whether or not health hazards might be expected from application of these alternative WCP.

The health hazards of the WCP application were separated into occupational hazards and environmental hazards. Occupational health hazards mainly occur during application of paints. Both professional and do-it-yourself painters are subject to these hazards, although the latter less frequently. Environmental health hazards arise from human exposure to air, (drinking) water, and food which may be polluted due to application or spilling of the paints. Moreover, environmental health hazards can be caused indirectly by ecotoxic effects caused by the paint constituents. The investigation described in this paper was set up to *a*) track down the composition of WCP; *b*) estimate the occupational and environmental exposure; and *c*) estimate the health hazards due to application of WCP.

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Methods

In The Netherlands, the main paint manufacturers, importers, and suppliers of raw materials are united into the Dutch Association of Paint and Printing Ink Manufacturers (VVVF). This association is therefore an excellent entrance and information transfer system for all aspects of paints. The VVVF provided a list of companies involved in construction painting (n = 19). A thorough survey during 1 year of advertisements in the trade journal for painters (Eisma's Vakpers) produced three more companies involved in WCP. Moreover, the latter survey was used to check the validity of the list given by the VVVF. The composition of WCP, like enamels, primers, and stains, was obtained by a questionnaire survey. The questionnaire was made up of two parts. The items of the product-specific part are shown in Table 1. To simplify the questionnaire, only the composition of the product with the major pigment (white or corrosion inhibiting) was asked for. To get further information about the composition (and toxicity) of the different constituents, the names of the producers of the constituents were requested. The general part of the questionnaire was designed to retrieve the expected sales in 1990. Producers were asked to fill in relative increases in sales. These figures were translated into absolute figures by the secretary of the VVVF. The VVVF also anonimized the questionnaires of its members; the other questionnaires were anonimized by the secretary of our department.

Exposures in the occupational environment and the general environment under normal conditions were estimated from the methods and conditions of application derived from the questionnaire (Table 1). Exposures in extreme conditions, like accidents, were not included in the hazard estimation. Moreover, the exposure to WCP due to smoking or eating with dirty hands is assumed to be easily avoidable. In this study, a worst-case approach was used, i.e., we assumed that *a*) all construction painting is performed with WCP; *b*) the concentrations of the paint constituents are the maximal concentrations encountered during our survey; *c*) painting is done in a small room (50 m^3) without ventilation or personal protection; *d*) the skin is cleaned only at the end of shift; *e*) during sewage treatment the paint constituents do not evaporate or absorb to soil (constituents); and *f*) the rate of metabolism to nontoxic metabolites is zero.

Table 1. Items in the product-specific part of the questionnaire on water-based construction paints.

Kind of product
Enamel, stain, primer, etc.
Application conditions
Indoor/outdoor
Substrates like wood, bricks, etc.
Type of construction industry like building, streets, etc.
Preparation of surfaces
Applications materials
Application temperature
Dilution
Liter per square meter substrate
Number of paint layers
Methods of removal
Concentration and names of producers of constituents
Main pigment, binder, etc.

Exposure from the occupational or general environment was derived from the physicochemical parameters of the constituents as a logic character (yes/no). In our worst-case approach, uptake by the lungs was set positive for the constituents with sufficient volatility to reach the lungs. Uptake by the skin is limited to compounds that have a relatively small molecular weight, which are not too soluble in water, and are not too lipohilic (Table 2).

The occupational and environmental health hazard of a constituent was obtained by multiplying the exposure with the toxicological hazard. The toxicological hazard of the constituent was derived from (eco)toxicity tests (Table 3). These toxicity data were tracked down from the literature, including the material safety data sheets provided by the suppliers of raw materials. Due to the limited data on humans and the lack of chronic animal experiments, frequently, data from acute and subchronic animal experiments and *in vitro* studies had to be used for the estimation of the toxicity of the paint constituents.

All health hazards were evaluated according to the worst-case assumptions. Moreover, our evaluation resulted in recommendations for diminishing the health hazards. To summarize the methods, a flow scheme of the method followed to analyze the health hazards of application of WCP is shown in Figure 1.

Results

The response of the VVVF members, based upon their estimated sales in 1990, was 80%. Detailed information about the composition of 42 water-based products was obtained from 14 manufacturers. The composition of two water-based wood preservatives and a paint remover was only partially reported.

The concentrations of functional components (binder, organic solvent, etc.) in the different kinds of water-based products are shown in Table 4. The mean (and also the median) amount of organic solvents was 6%. No organic solvents at all were present in the transparent and covering stains based on the linseed binder. No amines were reported in the primers.

Thirty-two of all paints (76%) were reported to be dispersions of polyacrylates. Four paints also contained a water-soluble alkyd resin and two others contained a mixture of polyacrylate and polyurethane. Three products contained a dispersion of linseed oil and some other resins. One floor coating was based on a two-component epoxyresin.

Acrylic dispersion paints (ADP), being the majority

Table 2. Exposure during application of water-based construction paints derived from the values of physicochemical parameters of the constituents.

Kind of exposure	Physicochemical	Boundaries	Exposure hazard (0 = no; 1 = yes)	Reference
Occupational				
Inhalation	Boiling point	< 150°C	0	(*20*)
	Particle size	< 5 µm	1	(*21*)
Dermal	Molecular weight	< 1000 D	1	(*22*)
	Water solubility	< 3 µmole/1	1	(*23*)
	Low P_{ow}[a]	< 3	1	(*24*)
Environmental				
Inhalation	Boiling point	< 150°C	0	(*20*)
	Particle size	< 5 µm	1	(*21*)
Dermal	Molecular weight	< 1000 D	1	(*22*)
	Water solubility	< 3 µmole/1	1	(*23*)
	Low P_{ow}[a]	< 3	1	(*24*)
Oral, water	Water solubility	< 3 µmole/1	0	(*25*)
	Biodegradation[b] BOD_5/COD × 100	< 50	0	(*25*)
Oral, food	Water solubility	< 3 µmole/L	0	(*25*)
	BOD_5/100 × 100	< 50	1	(*25*)
	Log P_{ow}	< 3	0	(*25*)

[a]P_{ow}, octanol-water partition coefficient.
[b]BOD_5, biological oxygen demand during 5 days; COD, chemical oxygen demand.

Table 3. Scores of (eco)toxicity tests and assigned toxicological hazards of constituents of WCP.

Test	Boundaries	Toxicological hazard	Reference
Acute oral toxicity, rat (LD_{50}, mg/kg)[a]	> 15,000	Not harmful	(*26*)
	5,000 – 15,000	Harmful	
	500 – 5,000	Toxic	
	50 – 500	Very toxic	
	5 – 50	Extremely toxic	
	< 5	Very extremely toxic	
Acute fish (daphnia) toxicity (LC_{50}, mg/L)[b]	> 100	Not harmful	(*27*)
	10 – 100	Harmful	
	10 – 10	Toxic	
	< 1	Very toxic	
Reproductive toxicity	Adequate studies with rat and rabbit	Toxic for reproduction	(*28*)
	Inadequate animal studies	Unknown reproductive toxicity	
Mutagenicity	Bacterial (± negative S9)[c] and nonbacterial test positive	Mutagenic	(*25*)
	One of the tests positive	Not mutagenic	
Carcinogenicity	Sufficient epidemiological evidence	Human carcinogen	(*29*)
	Sufficient animal experimental evidence	Probably human carcinogen	
Skin irritation test	No irritation	No skin irritant	(*30*)
	Slight irritation	No skin irritant	
	Intermediate irritation	Slight skin irritant	
	Strong irritation	Strong skin irritant	
	Corrosive	Corrosive for skin	
Guinea pig maximization test	Low	Not skin allergen	(*31*)
	Medium	Slight skin allergen	
	High	Strong skin allergen	

[a]LD_{50}, dose that causes 50% mortality within 14 days.
[b]LC_{50}, concentration that causes 50% mortality within 24 to 96 hr.
[c]S9, metabolizing supernatant of rat liver microsomes.

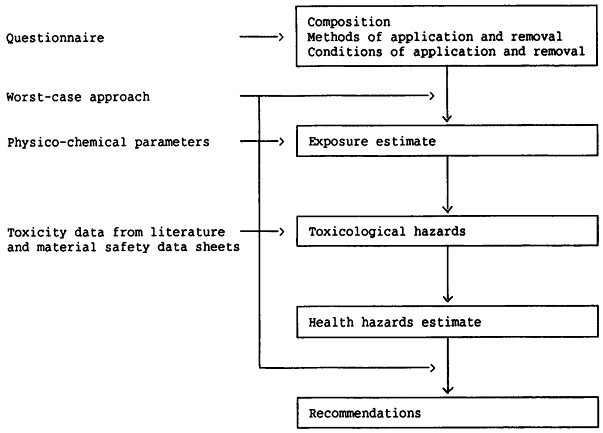

FIGURE 1. Flow scheme of the method used to analyze the occupational and environmental health hazards from application of WCP.

Table 5. Presence of functional components in the most commonly occurring water-based (acrylic dispersion) and solvent-based (alkyd paint) construction paint.[a]

Functional component	Acrylic dispersion	Alkyd paint
Binder	+ (polyacrylate)	+ (alkyd resin)
Pigment	+	+
Filler	+	+
Organic solvent	+ (0–15%)	+ (about 50%)
Ammonia	+	–
Amine	+	–
Preservative	+	–
Surfactant	+	–
Corrosion inhibitor	+	–
Thickener	+	+
Drier	–	+
Anti-skinning agent	–	+
UV absorber	+	–

[a](+) Present, (–) not present.

of WCP reported, contain a number of functional components that are not present in traditional solvent-based construction paints (alkyd paints) (Table 5) and which are discussed below. Some examples of these chemicals are given in Table 6. WCP also contain very specific organic solvents and preservatives. Because of this specific prevalence and their toxicological hazards, both groups of chemicals are listed extensively in Table 7 (preservatives) and Table 8 (organic chemicals).

Organic solvents are added to ADP for several reasons. The main reason is their function in film formation. Preservatives are used for conservation of the binder and the paint during production and storage; moreover, these products contain bacteria-degradable compounds, like surfactants in an aqueous environment, and these products contain the nitrogen source of ammonia. Ammonia and volatile amines are used to stabilize the binder and the paint at a pH of 8 to 9. Less volatile amines create a longer "open time" after application. The water-soluble alkydresin is solubilized with triethylamine. Surfactants include antifoaming agents and emulsifiers of the binder, filler, thickener, and /or pigment. Corrosion inhibitiors are needed to prevent corrosion of metallic paint cans and metallic parts of the painted material. UV absorbers are essential in paints for wood because ADP do not absorb the wood-destroying UV radiation.

Table 6 also contains some information about the health hazards of some WCP constituents. When the hazard cannot be excluded, it is coded +; it is coded ++ when the concentration of a compound in the paint leads to an occupational or general environmental concentration that is able to cause a toxic effect. The health hazards of application of WCP estimated according to the worst-case approach can be found in the right column of Table 9. The main occupational health hazards are

Table 4. Concentrations of functional components in different kinds of water-based construction paints (mean and range of weight percentage).

Component	Enamels (15)[a]		Stains (10)		Primers (7)		Others (10)[b]		Total (42)	
Binder	23	(1–30)[c]	26	(20–40)	20	(18–23)	30	(9–52)	9	(9–52)
Pigment	18	(1–25)	4	(0.5–25)	21	(15–26)	15	(0–41)	15	(0–41)
Filler	3	(0–14)	0.3	(0–1.4)	12	(8–20)	11	(0–66)	5.5	(16–90)
Solids	44	(22–60)	30	(16–53)	56	(46–85)	57	(27–90)	45	(16–90)
Ammonia[d]	0.05	(0–0.1)	0.03	(0–0.01)	0.07	(0–0.1)	0.02	(0–0.1)	0.04	(0–0.1)
Amine	0.04	(0–0.3)	0.05	(0–0.5)	0	(0–0)	0.07	(0–0.5)	0.05	(0–0.5)
Organic solvent	7	(3–11)	5	(0–10)	5	(2–9)	5	(0–10)	6	(0–11)
Surfactant	2	(0–5)	1	(0.3–5.5)	3	(1–6)	0.8	(0–3)	2	(0–6)
Thickener	1	(0–4)	1	(0.1–3)	1	(0.1–3)	1	(0–3)	1	(0–4)
Preservative	0.3	(0.01–1)	0.7	(0.04–3)	0.9	(0–2)	0.2	(0–1)	0.5	(0–3)
Corrosion inhibitor	0.1	(0–0.7)	0.01	(0–0.1)	0.3	(0–1)	0.07	(0–0.7)	0.1	(0–1.0)
Others[e]	0.4	(0–)	0.2	(0–0.5)	0.1	(0–0.3)	0.5	(0–4.1)	0.3	(0–4.1)

[a]Number of paints in parentheses.
[b]Varnish, transparent enamel, transparent primer, floorcoating, covering stain, and combination of primer and enamel.
[c]Range in parentheses.
[d]The ammonia present in the binder is not incorporated.
[e]UV protector, plasticizer, drier, etc.

Table 6. Occupational and environmental health hazards due to application of WCP that contain compounds with toxicological properties.[a]

Compound	Maximal concentration, % weight	M	SC	Other systemic mammalian toxicity	Skin S	Skin Ir	Mucous irritation	Odor	Fish lethality
Binders and their constitutents									
Polyacrylate	37	–	–	–	–	–	–	+	++
Methyl methacrylate	0.14	+	–	?	+	+	+	+	–
Acrylonitrile	0.006	+	+	?	?	+	+	+	+
Butyl benzylphthalate	1.4	–	–	?	+	?	–	–	+
Ammonia and amines									
Ammonia	0.18	–	–	Lung	–	–	+	+	+
Dimethyl ethanolamine	0.2	–	–	Nitrosable	?	–	+	+	?
Triethylamine	1.0	–	–	Eyes, lung Nitrosable	?	+	+	+	+
Corrosion inhibitors									
Triethanolamine	0.07	–	–	Nitrosable	+	+	–	–	?
Sodium nitrite	0.02	+	–	Nitrosable	–	–	–	–	+
Preservation									
Formaldehyde	0.1	+	+	Liver	+	+	+	+	+
(Chloro)methylisothiazolinon	(0.003) 0.001	–	–	?	++	+	–	–	+
Organic solvents									
Ethylene glycol	7.9	–	–	Kidney, teratogenicity?	–	–	–	–	+
Ethylene glycol ethyl ether	2.0	–	–	Blood cells, teratogenicity	–	–	+	+	–
Diethylene glycol butyl ether	5.0	–	–	–	–	–	–	–	?
Surfactants									
Poly(oxyethylene)octyl phenylether	1.6	–	–	?	?	+	–	–	++
Tributylphosphate	0.1	–	–	Nervous system	?	+	–	–	+
Others									
Ammonia bichromate	1.0	–	–	?	++	+	–	–	+
Hydroxymethylphenylbenzotriazol	0.4	–	–	?	+	?	–	–	?

[a]An appendix to this table (the toxicological literature references) is available on request. Abbreviations: (–) no health hazard; (+) health hazard not excluded; (++) health hazard expected; (?) unknown, insufficient data. (M) Mutagenicity; (SC) suspected carcinogenicity; (S) sensitization; (Ir) irritation.

irritation of mucous membranes due to the volatile monomers, organic solvents, amines, ammonia, and formaldehyde and irritation of the skin by monomers, organic solvents, preservatives, and detergents. Irritation of mucous membranes may result in headache (*1*) and acute and chronic respiratory disorders (*7*). Ortho-

Table 7. Preservatives in water-based construction paints.

Chemical name	CAS no.[a]	Maximal concentration, % weight	Prevalence, % of paints reported
Bacteriocides			
1,2-Benzisothiazolin-3-one	2634-33-5	0.05	9
Tetrachloroisophtalonitrile	139-08-2	0.5	5
Alkylammonia+ isothiazolin + formol derivatives[b]	—	3.0	21
5-Chlor-2-methyl-4-isothiazolin-3-one	26172-55-4	0.003	31
2-Methyl-4-isothiazolin-3-one	2682-20-4	0.001	17
N-Methyl-chloracetamide[b]	2832-19-1	0.01	2
2-[(Hydroxymethyl)amino]-ethanol[b]	34375-28-5	0.1	2
2-[(Hydroxymethyl)amino]-2-methylpropanol[b]	52299-80-4	0.2	2
Fungicides			
2-*n*-octyl-4-isothiazolin-3-one	26530-20-1	0.20	5
Carbendazim	10605-21-7	0.20	2
3-Iodo-2-propynyl butyl carbamate	55406-53-6	0.3	2
2-Sodiumpyridin-*N*-oxide	3811-73-2	0.01	2

[a]CAS no., Chemical Abstract Service number.
[b]Formaldehyde-releasing compounds.

Table 8. Organic solvents in water-based construction paints.

Chemical name	CAS no.[a]	Maximal concentration, % weight	Prevalence, % of paints reported
Hydrocarbons			
White spirit	64742-88-7	3.6	9
Esters and others			
Isobutylesters of dicarboxylic acids	—	2.0	5
2,2,4-Trimethyl-1,3-pentanedial monoisbutyrate	25265-77-4	5.0	26
N-Methyl-2-pyrrolidone	872-50-4	1.7	14
Glycols			
Ethylene glycol	107-21-1	7.9	12
Propylene glycol	57-55-6	7.9	57
Glycolethers			
Ethylene glycol ethyl ether	110-80-5	2.0	7
Ethylene glycol phenyl ether	122-99-6	2.5	12
Ethylene glycol butyl ether	111-76-2	3.0	5
Diethylene glycol ethyl ether	111-90-0	3.0	5
Diethylene glycol butyl ether	112-34-5	5.0	26
Propylene glycol-1-methyl ether	107-98-2	2.1	12
Dipropylene glycol-1-methyl ether	34590-94-8	7.0	12
Butyleneglycol-3-methyl ether	2517-43-3	5.0	12

[a]CAS no., Chemical Abstract Service number.

ergic eczema may occur due to frequent skin contact with WCP combined with scouring and extreme climate conditions. Such an eczema ameliorates the barrier function of the skin, causing toxic compounds to penetrate more easily through the skin in to the body.

Another important occupational health hazard is sensitization of the skin caused by monomers and preservatives, which can result in allergic eczema. Suspected carcinogenic hazards are presented by some ADP due to percutaneous or lung uptake of the suspected carcinogens acrylonitrile and formaldehyde. The suspected teratogens ethylene glycol and ethylene glycol ethylether present suspected teratogenic hazards. Data on other systemic toxicity due to skin uptake of monomers, preservatives, and some other components that are specific for WCP are lacking.

Table 9. Comparison of the health hazards due to application of solvents-based construction paints and their water-based alternatives.[a]

Health hazard	Organic solvents-based construction paints	Water-based construction paints
Acute and chronic neurotoxicity	+	–
Carcinogenicity	+	± (formaldehyde)
Teratogenicity	±	± (ethylene glycolethers)
Mucous membrane irritation	+	±
Skin irritation	+	±
Skin sensitization	–	±
Annoying smell	+	±
Ozone generation	+	–
Fish toxicity	+	+
Bacterial toxicity	–	±

[a](+) Health hazards reported; (±) health hazards expected based on animal toxicity data; (–) no health hazards expected.

The annoying smell of WCP due to monomers, some organic solvents, and volatile amines causes an occupational or environmental health hazard. Environmental health hazards may occur when drinking water contains the less degradable organic solvents like ethylene glycol butyl either (Dow Chemical Europe, personal communication), preservatives like chloromethyl isothiazolinone (*9*), and detergents like poly(oxyethylene) octyl phenyl ether (*10*). The less degradable polyacrylate binder in ADP will not reach drinking water, while it is flocculated during purification of superficial water (*11*).

Indirect health hazards are caused by fish toxicity of the slowly degradable polyacrylate-binder (*12*) and the inherent bacterial toxicity of preservatives. This bacterial toxicity results in diminution of bacterial purification during sewage treatment. Whether or not there are health hazards due to toxicity of paint constituents to soil organisms is unknown.

Discussion

The aim of this study was to describe the health hazards of WCP, assuming a total switch to this type of paint in construction painting. The health hazards were separated into hazards from occupational and environmental exposure. The first hazards are restricted to professional painters and, to a lesser degree, to do-it-yourself painters. The latter hazards concern the whole population. This group is exposed to polluted air, (drinking) water, and food caused by the application or spilling of paints. Moreover, indirect environmental health hazards can be caused by ecotoxic effects of paint constituents.

The composition of the WCP reported in this study is similar to that reported in a recent Danish survey (*1*). In the Danish study, eight products were chemically analyzed to check the validity of the questionnaire data, and only minor deviations were observed. Therefore, we assume that our data on the composition of WCP are valid as well.

It has to be stressed, however, that the composition reported in our study was retrieved during a short time span (2 months) in 1987 and that WCP are a strongly developing product. In the meantime, new binders (vinylacetate/vinylversoate) without volatile, strong-smelling constituents are available for glossy dispersion paints for the construction trade (*13*). Only white paints were studied, since they make up 80% of the present sales. Color pastes used can add percentages of about 3.5% ethylene glycol, 0.5% detergent, and an unknown percentage of preservatives to WCP.

The external exposure and the uptake of the paint constituents were only roughly estimated, mainly based on physicochemical properties of the paint constituents. An exception to this is the glycol ethers. Due to the suspected male reproductive toxicity of ethylene glycol ethers (*14*), more detailed information is available about these solvents. The glycol ethers evaporate a few hours after application of the WCP (*1*) and are readily absorbed by the lungs and skin due to their high blood-air partition coefficients (*15*) and solvent properties (*16*).

The WCP reported during our questionnaire-survey contained at least five times less organic solvents than the traditional paints. WCP linseed oil and some other resins serving as the binder contained no organic solvents. Therefore, the hazard to acute and/or chronic neurotoxicity and irritating effects on the airways due to painting is reduced. However, during and after application, ADP can present some other health hazards: irritation of the mucous membranes of eyes and airways and skin irritation and sensitization. This is in accordance with the Danish study in which irritation of nose and eyes were mentioned as the main complaints of WCP users (*1*). In The Netherlands, 10 to 15% of the population is bronchial hyperreactive to irritating compounds (*17*). About 15% of the population is atopic, resulting in a higher risk of getting orthoergic eczema (*18*). Persons with orthoergic eczema and pregnant women have a higher risk of getting allergic eczema (*19*). Some ADP contain compounds that should be regarded to be able to cause hematotoxicity, teratogenicity, and carcinogenicity.

Environmental health hazards from ozone due to volatilization of organic solvents from the paints are reduced strongly by using WCP. However, cleaning application materials of WCP under the tap can cause a significant burden to sewage treatment due to some slowly degradable compounds. One of them (polyacrylate) was reported also to clog the gills of fish (*12*). When WCP are spilled to the soil, the water-soluble preservatives and slowly degradable compounds may affect soil organisms. Data on the latter hazard are lacking.

Table 10. Recommendations for substitutions or reduction of components to reduce the health hazards during the application of WCP.

Actual	Alternative
0.1% monomers	< 0.01% monomers
Volatile amines	Less irritating amines
Ammonia	Sodium hydroxide
Nitrite	Sodium benzoate
Formaldehyde	Gamma radiation + nonvolatile enzyme inhibitors[a]
Ethylene glycol	Propyleneglycol
Ethylene glycol ethers	Nontoxic, rapidly degradable organic solvents
Poly(oxyethylene)-octylphenylether	Poly(oxyethylene)octyl ether
Ammonia bichromate	Nontoxic, film-forming compound

[a]Gamma radiation of the paint or its constituents using the rapid decaying cobalt 60($t_{1/2}$ = 5.27 years) (*32*) combined with the addition of a small amount of benzisothiazolinone and carbendazim as enzyme inhibitors and paint film preservative, respectively.

In a survey, it is common practice to compare the new situation to the old one. In Table 9, a comparison is made between the health hazards due to the application of the traditional, organic solvent-based, construction paint (OCP) and their water-based alternatives (WCP). The WCP are not likely to provoke acute and/or chronic neurotoxicity. Moreover, the irritation of mucous membranes and skin will be lower. The majority of WCP contain only suspected carcinogens, while OCP contain (small amounts of) the proven human carcinogen benzene. A new health hazard caused by the application of WCP is, however, introduced: skin sensitization. Health hazards due to ozone generation will be reduced by substituting OCP with WCP. However, water pollution can be caused both by OCP and WCP. Recommendations for the reduction of the health hazards from application of WCP by source manipulation are shown in Table 10.

Another way to reduce health hazards is good occupational and environmental hygiene. Application in a small room should be done under strong ventilation (air change rate > 5 if paints contain triethylamine, formaldehyde or ethylene glycol ether). Protection, frequent cleaning, and taking care of wounds on the skin can prevent irritation and sensitization and absorption of toxic compounds. Application materials should not be cleaned under the tap, but kept overnight in a container with water. This waste water and the liquid rests of ADP should be treated like chemical waste.

In conclusion, before total use of WCP is stimulated, more data should be available on the real environmental exposure during application of WCP and/or on the health of painters using WCP for a longer period (e.g., in Scandinavian countries). In the meantime, our approach of the hazard estimation can be used to assess the health hazards of new or substituting compounds in WCP.

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